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# PENAEID SHRIMP HATCHERY SYSTEMS

by

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Contents



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## Abstract

The Japanese system for rearing larval shrimp is compared with the hatchery culture system developed at the National Marine Fisheries Service, Gulf Coastal Fisheries Center, Galveston. Procedures, initial construction costs, and operational costs are presented for both systems. Aspects of each approach which make it advantageous or disadvantageous are considered. Lists of the necessary equipment are included, and costs of production with each system are calculated on a comparative basis. The facility costs are greater for the Japanese method than for the Galveston method. Algal culture equipment is required for the Galveston method, but not for the Japanese approach. Operating costs are slightly higher for the Galveston method. Site requirements are more restrictive with the Japanese approach, and more spawning females are required than with the Galveston method.

## Extracto

El sistema japonés para el cultivo de larvas de langostino, es comparado con el desarrollado por el National Marine Fisheries Service, Gulf Coastal Fisheries Center, en Galveston. Se presentan los procedimientos, costos iniciales de construcción, y costos operacionales para ambos sistemas. Se consideran los aspectos de cada sistema, que lo hacen ventajoso o desfavorable. Son incluidas listas del equipo necesario y se calculan los costos de producción para ambos sistemas de una forma comparativa. Los costos de instalación son mayores en el sistema japonés que en el método de Galveston, aunque son necesarios equipos para el cultivo de algas en el método de Galveston, y no en el japonés. Además los costos de operación son ligeramente mayores en el sistema de Galveston. Los requerimientos para la instalación son más restrictivos en el sistema japonés y se necesitan más hembras grávidas que no con el sistema de Galveston.


## 1. INTRODUCTION

In spite of the strong interest in shrimp culture in South and Central America, and the numerous pilot commercial shrimp farms presently in operation, most culture efforts have not reached the point of profitable operation. High costs associated with shrimp farming ventures raise questions regarding the probability of profitable shrimp culture within the next few years.

As far as we know, Japan is the only country in the world that has been able to culture shrimp profitably from the egg to market-sized adults. At the Tokyo Central Fish Market, live "Kuruma-Ebi" shrimp (*Penaeus japonicus*) bring a price of U.S.$ 7 to 10/kg (Shigueno, 1972). This price is high compared with the United States price of $ 3.80/kg due to the fact that the Japanese people demand live shrimp for the preparation of a delicacy known as "tempura". In Japan, costs continue to rise, while production is remaining about the same. Wages are increasing, as well as the cost of fresh natural foods used to feed the shrimp. However, the Japanese are well aware of the problems, and are actively engaged in developing more efficient techniques and an artificial diet.

A major cost in shrimp culture is the rearing of larvae. Two distinct methods of rearing shrimp larvae are used successfully, and in this paper these methods are compared in order to give a prospective shrimp farmer a basis for choosing the most suitable method for his particular situation.

## 2. CULTURE TECHNIQUES

### 2.1 Japanese method

As the Japanese fisherman brings a part of his shrimp catch back to shore alive, gravid females are acquired by the shrimp hatcheries at a minimal cost. Females usually have to be transported only a few kilometres, because the hatcheries are constructed near landing facilities. Since the water temperature plays such an important role in the growth of the shrimp, the water is heated by pumping steam through a network of pipes within the tanks. To aid in this process, and to utilize natural sunlight for photosynthesis, hatcheries are built in green fibreglass houses. The tanks are constructed with one air stone/3 $m^2$ of tank bottom. The air source is usually a 5 hp blower for 10 tanks 10 x 10 x 2 m. Seawater pumped directly from the sea is filtered either with a sand filter or a fine mesh screen (80–100 mesh) depending on the amount of suspended particulate material in the water. A salinity range of 27–35 ppt is most desirable (Shigueno, 1972; Hudinaga, 1942; Hudinaga and Miyamura, 1962).

Once the gravid female shrimp arrives at the hatchery, 50 to 60 are placed in each tank (10 x 10 x 2 m) just before sunset (Shigueno, 1972). Spawning usually occurs on the first evening, but the adult shrimp are not removed until the morning of the third day. As soon as nauplii are observed, the water is fertilized daily with 50 g of potassium nitrate and 5 g of potassium phosphate (dibasic). The amount of nutrient salts added per $m^3$ of water is dependent upon the level of phytoplankton in the water (Shigueno, 1972); initial water depth is 0.5 m. By the time the larval shrimp metamorphose to the protozoeal stage (about 35 hours), the fertilizer will normally have caused a natural phytoplankton bloom. It is in the protozoeal stage that shrimp begin feeding. Through experimentation it has been shown that a pure culture of the diatom Skeletonema costatum is suitable for feeding the protozoeal stages (Hudinaga, 1942); this technique, however, is not practised today in Japan on a commercial scale. Instead a natural bloom of diatoms such as Melosira, Thalassiosira, Nitzschia, Rhizosolenia and Skeletonema occurs (Shigueno, 1972). If a suitable bloom does not occur, soybean cake, a by-product of the soy sauce process, may be ground and fed to the shrimp (Hudinaga and Miyamura, 1962; Hudinaga and Kittaka, 1967; Hudinaga, 1969).

The average time required for the shrimp to metamorphose from first naupliar stage to the mysis stage is about eight days. During the mysis stages, shrimp feed on phytoplankters and zooplankters that are growing in the tank. After three more days, the shrimp are first-stage postlarvae, and are fed freshly hatched Artemia salina until the fourth day of the post-larval stage. This usually requires about 500 g of Artemia eggs per day per tank (Shigueno, 1972; Mock, 1973).

### 2.2 Galveston method

The Galveston method differs from the Japanese approach in that the algal foods are raised separately and fed in pre-determined quantities. Much smaller tanks are used, and the density of larval shrimp reared in the tanks is about 100 times greater.

#### 2.2.1 Algal culture

Rearing the algae required as food is the most difficult aspect of this approach to the culture of larval shrimp. Before 1970, it was our theory that live algae were necessary as food for larval shrimp (Cook and Murphy, 1966). Since we had not been able to induce captive female shrimp to mature sexually in the laboratory, we used natural stocks for our spawners. Availability of spawners was dependent upon weather, seasonal distribution and other factors. We maintained, therefore, continuous unialgal cultures so that when spawners were available, algae would also be available. This practice required a great deal of time, labour and expense. It was necessary to harvest a portion of the culture daily, and to add fresh sea water and nutrients daily. Since no methods of preserving algae were known, portions of the culture frequently had to be discarded (Kanslow, MS).

We also knew from past experience that unialgal cultures could not always be maintained in natural sea water and, therefore, the commercial synthetic sea salt "Instant Ocean"1/ was chosen, which along with tap water and nutrients has proven to be a reliable medium. For example, 300 l of S. costatum at a density of 3.5 - 5.0 x $10^6$ cells/ml can be cultured with dependability from a 10 ml tube starter culture in 16 days (Mock, 1974). Although this was a satisfactory means of culturing algae, the medium in which the algae had been raised was slightly toxic to the larval shrimp. Preliminary research revealed that the algae could be separated and concentrated in a continuous flow centrifuge if the speed was controlled. For separation and concentration, a cream separator has proven to be very satisfactory (Mock, 1971). Although larval shrimp can be grown utilizing only S. costatum, more rapid growth has been observed when another alga, Tetraselmis, is fed after the shrimp reach the protozoea II stage. This flagellate is also grown in Instant Ocean, and concentrated using the cream separator. Tetraselmis cultures reared following the same time schedule used for Skeletonema reach densities of 3.3 - 4.0 x $10^5$ cells/ml at the time of harvest (Griffith, Kenslow and Ross, 1973).

The time required from inoculation of either Skeletonema or Tetraselmis in a 10 ml test tube to a 300 l culture tank (ready for harvesting), is 16 days (Fig. 1). With a culture system utilizing ten 300 l tanks, a tank of each species can be harvested daily. Sufficient algal cells to rear 1 200 000 larval shrimp can be produced in 20 days. However, once the system is set in motion, a back-log of cells is prepared, and between mass culture periods the only need is to maintain the stock tube cultures. Since a desired feeding level can be predetermined and the volume of the rearing container is known, given amounts of concentrated algal cells are measured into suitable containers to be either:

(a) fed fresh, if timing of the larval shrimp experiment should correspond with that of the algal culture, or

(b) frozen to be used at a later date.

2.2.2 Larval culture

As with the Japanese approach, gravid female shrimp are acquired from natural stocks. Once the shrimp are brought into the laboratory, they are acclimated to temperature and placed in individual 14 l spawning carboys. It is desirable that the water temperature be 28.0° - 28.5°C with a salinity of 28-30 ppt. Although the female will spawn at a lower temperature, the survival of the larvae will be poor below 28°C. Spawning shrimp individually enables the eggs to be selected and distributed, or discarded, as required. Dead females, and infertile or aborted eggs are eliminated.

The rearing container is a round fibreglass tank, approximately 1 900 l, with a conical bottom fitted with 4 air-lift pipes (Salser and Mock, MS); half a million shrimp can be reared to the postlarval stage in this tank).

Routine monitoring of grazing levels, and counting of the population during each rearing experiment, has enabled feeding levels to be adjusted for optimum efficiency. Once the density of the larval shrimp population is determined, feeding levels can be accurately adjusted to provide adequate food with minimal waste. Feeding is accomplished by initially building up a standard level of algae in the rearing tank, then adding sufficient cells to replace those which the larval shrimp consume. This can be accomplished by pouring the food in the tank, or by using an automatic feeding pump.

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1/ Use of trade names does not imply endorsement of commercial products based on current electrical rates in Galveston. Since the algal cultures are grown in a synthetic medium, they can be grown anywhere. The algae may be grown in mass cultures, concentrated, and frozen to be used at a later date.

## 4. COMPARISON OF SYSTEMS

Although the equipment and structures necessary for the production of penaeid postlarval shrimp will vary from one locality to another, the basic units required are similar. In order to arrive at comparable costs, current building, equipment, utility and labour costs have been chosen.

For purposes of comparing the two approaches to algal culture Tables I and II have been prepared. In Table I the costs of facilities and equipment are tabulated based on prices in Galveston, Texas. Cost of the production facility is higher for the Japanese method chiefly because of the size of the tank used for rearing the larvae. A major cost factor with the Galveston system is the cost of algal culture equipment, an expenditure not incurred when the Japanese approach is used. Algal culture equipment required with the Galveston method includes: algal culture tanks, light fixtures, an autoclave, balances, a microscope, a milk separator, pumps, a freezer and miscellaneous glassware and fittings.

Shrimp boats to collect female shrimp can be leased for U.S.$ 550 a trip in Galveston. The average catch per trip varies from 10-15 gravid females, and the average number of eggs spawned per female is 100 000. To produce 1 200 000 postlarval shrimp using the Japanese method would require 40 females at a cost of U.S.$ 2 200 (assuming 30 percent survival from egg to postlarvae). To produce 1 200 000 postlarval shrimp using the Galveston method would require 15 females at a cost of U.S.$ 550 (assuming 80 percent survival from egg to postlarvae).

Labour costs may vary considerably between countries. Generally speaking labour costs could be used more efficiently as the size of the operation is increased. The principal production costs are the costs of labour, and these are considerably higher with the Galveston method than with the Japanese method (Table II).

## 5. DISCUSSION

Essential requirements for the development of any shrimp hatchery include the availability of spawners, a suitable water supply, a dependable electrical supply, and skilled technicians. Regardless of the approach used, a hatchery will not be successful without these basic components.

The Japanese approach requires a higher initial investment, and less technical expertise than the Galveston approach. The algal culture techniques required for the Galveston method require skilled technicians. The production per unit of water volume is much lower with the Japanese method, and survival from eggs to postlarvae will typically average 10% - 30% with Japanese system and 70% - 80% with the Galveston system. In addition the dependability of the Galveston system is greater because known feeds are fed in known quantities.

The ultimate decision as to which approach is most appropriate for use in a particular situation will depend on a variety of cost factors, the availability of technical personnel, and the specific functions of the hatchery.

## TABLE I

Basic facility and equipment costs for the Japanese and Galveston systems of larval shrimp culture (systems designed to produce 1 200 000 postlarval shrimp per hatch)

| Japanese System | | Galveston System | |
|---|---|---|---|
| 1 Concrete tank 10 x 10 x 2 m with valves, filtres and fittings | $ 20 700 | 3 Fibreglass tanks (2000 l) with valves, filters and fittings | $ 1 800 |
| Air blower | 540 | Air blower | 300 |
| Water pumps | 300 | Water pumps | 125 |
| Steam heat exchanger | 3 000 | Electric heaters | 60 |
| | | Algal culture equipment | 13 300 |
| Total | U.S.$ 24 540 | Total | U.S.$ 15 585 |

## TABLE II

Operating costs of the Japanese and Galveston style hatcheries to produce 1 200 000 postlarval shrimp

| Japanese System | | Galveston System | |
|---|---|---|---|
| Gravid females | $ 2 200 | Gravid females | $ 550 |
| Labour: | | Labour: | |
| biologist (14 days) | 672 | biologist (14 days) | 672 |
| technician (14 days) | 288 | technician (14 days) | 288 |
| Fertilizer | 20 | Media for algal culture | 187 |
| <u>Artemia</u> | 40 | Labour: | |
| Utilities | 50 | biologist (20 days) | 1 120 |
| | | tecnnician (20 days) | 480 |
| | | <u>Artemia</u> | 20 |
| | | Utilities | 75 |
| Total | U.S.$ 3 270 | Total | U.S.$ 3 392 |

Note: The costs of taxes, interest and depreciation have not been included in these calculations.

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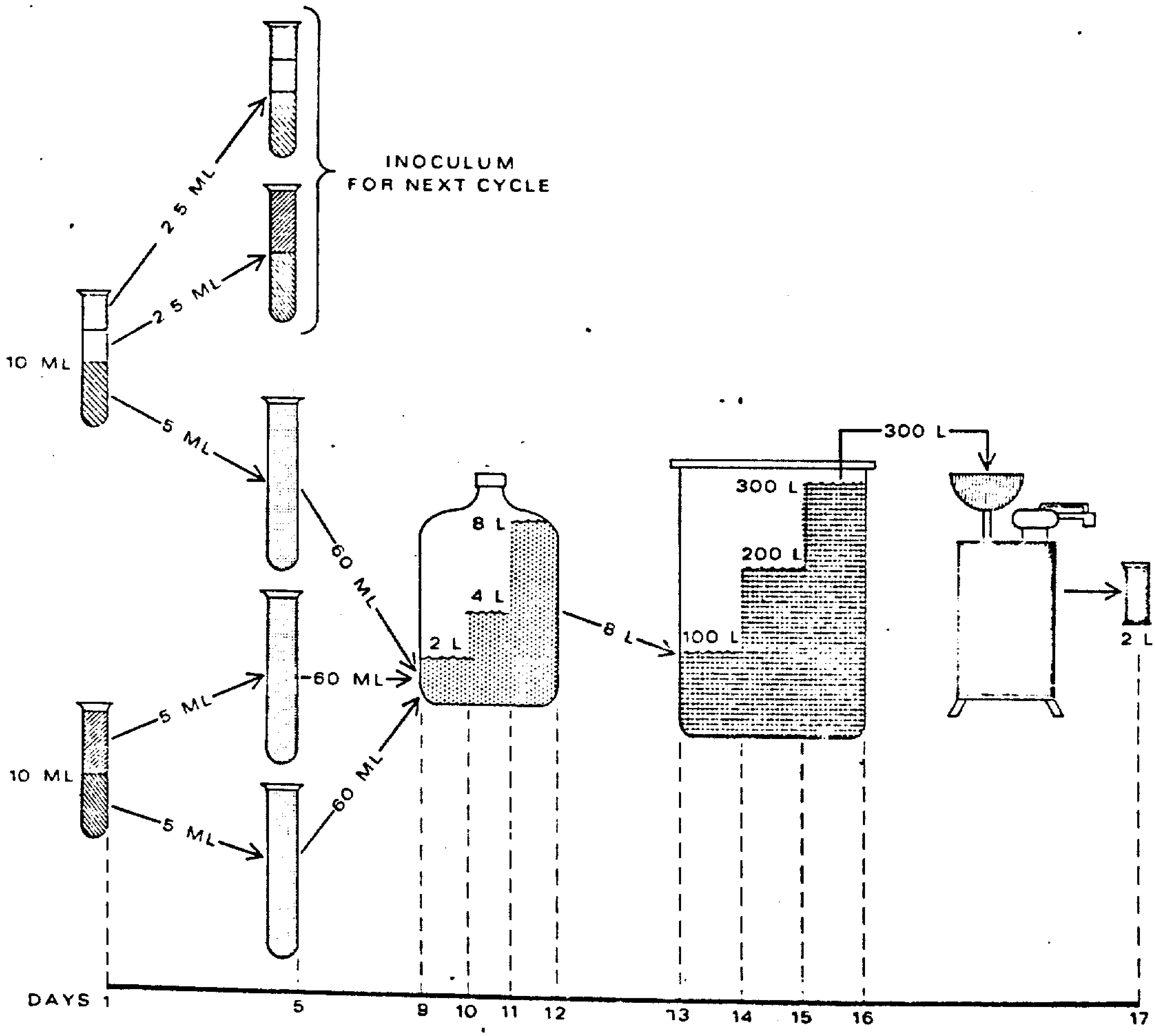


Figure 1. Cycle for cultivating algae in 300 litre units

## APPENDIX I

### Costs of rearing penaeid shrimp to postlarvae

**Japanese Hatchery Facility 1/**

| | | |
|---|---|---|
| Concrete hatchery tank (10 x 10 x 2 meters); structure will require about 43 $m^3$ of concrete. | $20,000 | |
| Fittings (valves, pipe, filters) | 700 | |
| Hatchery structure, optional | --- | |
| Air-blower 2 hp, 1.8 $m^3$/minute | 540 | |
| Water pump 3 hp, 760 liters/minute | 300 | |
| Steam boiler and heat exchanger 25,000 liters/hour | 3,000 | |
| | $24,500 | $24,500 |
| Labor: supervisor, $7.00/hour 2/ | 672 | |
| technician, $3.00/hour | 288 | |
| | $ 960 | $25,500 |
| Cost of gravid females 3/ | $ 2,200 | $27,700 |
| Utility cost for 14 days of operation | $ 50 | $27,750 |
| Fertilizer cost to rear 1,200,000 postlarvae shrimp. | $ 20 | $27,770 |
| *Artemia* (2000 grams) | $ 40 | $27,810 |
| Cost to rear 1,200,000 postlarval shrimp | | $27,810 |

1/ Site cost, interest and depreciation not included.

2/ Calculated on a 48 hour work week, for 2 weeks.

3/ Shrimp boats lease for $550 a trip.

4/ Calculated on 8 hours aday for 20 days.

**Galveston Hatchery Facility 1/**

| | | |
|---|---|---|
| Fiberglass hatchery tank (2000 liters) | $300 | |
| Fittings (valves, pipe, filter) | 200 | |
| Hatchery structure, optional | ---- | |
| Compressor 1/3 hp, 0.07 $m^3$/minute | 100 | |
| Water pump 1/3 hp, 95 liters/hour | 125 | |
| Immersion electric (75 watts) water heater (3) | 30 | |
| | $755 | $755 |
| Labor: supervisor, $7.00/hour 2/ | $672 | |
| technician, $3.00/hour | 258 | |
| | $960 | $1,715 |
| Cost of gravid females 3/ | $550 | $2,265 |
| Utility cost for 14 days of operation | $ 10 | $2,275 |
| 500,000 postlarval shrimp can be produced in one hatchery tank. Each additional tank requires an expenditure of $600 (including all fittings). Equipment to produce 1,200,000 postlarval would require 2 additional tanks. | $1,200 | $3,475 |
| Algal laboratory structure (5 x 10 meters) | 5,000 | |
| Temperature control equipment | 500 | |
| Primary culture room (2 x 3 m), temperature controlled | 200 | |
| Ten algal mass culture tanks (90 x 60 x 60 CM, 300 liters each) | 1,000 | |
| Instant Ocean storage tank (1600 liters) | 200 | |
| Four 38 CM light banks with fixtures and lamps | 1,000 | |
| Air compressor, 3/4 hp | 155 | |
| Fittings | 345 | |
| Autoclave | 600 | |
| Balance, top loading | 500 | |
| Balance, anlytical | 200 | |
| Compound microscope | 500 | |
| Cream Seperator | 2,000 | |
| Peristaltic pump (700 liters/hour) | 100 | |
| Freezer | 250 | |
| Refrigerator | 250 | |
| Misc. fittings and glassware | 500 | |
| | $13,300 | $16,775 |
| Algal costs to rear 1,200,000 larval shrimp *Skeletonema* ($0.04 per liter) | $ 53 | |
| *Tetraselmis* ($0.04 per liter) | 133 | |
| | $ 186 | $16,961 |
| Labor: supervisor $7.00/hr 4/ | $1,120 | |
| technician $3.00/hr | 480 | |
| | $1,600 | $18,561 |
| Utility Cost | $ 65 | $18,626 |
| *Artemia* (1,250 grams) | $ 22 | $18,648 |
| Two fiberglass (100 liter) *Artemia* hatching tanks | $ 100 | $18,748 |
| One fiberglass (2,000 liter) water storage tank | $ 300 | $19,048 |
| Cost to rear 1,200,000 postlarval shrimp | | $19,048 |